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DETERMINATION OF TECHNICALLY FEASIBLE DEVELOPMENT STRATEGY TO PRODUCE UNCONVENTIONAL TIGHT GAS SAND RESERVOIR

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ABSTRACT:

Exploitation of unconventional resources is changing the global energy landscape day by day. The depletion of conventional resources and high oil and gas demands have shifted the attention towards such resources. Their development is also very challenging. However, advancement in technologies such as hydraulic fracturing and horizontal drilling boost up the exploitation tendency of these invincible assets.

This paper deals with the determination of technically feasible development strategies in unconventional tight gas sand reservoir. Tight reservoirs have been characterized by low porosity and low permeability. Hence, a single-porosity simulation model of tight gas sand reservoir has been developed which describes the behavior of gas flow in small pores of the reservoir.

Various development strategies can be employed for tight gas reservoirs. The selection of best strategy involves the technical and economic feasibility of reservoir. The strategies include Vertical well, Horizontal well, Vertical well with hydraulic fracture and Horizontal well with hydraulic fractures. Sensitivity analysis has been carried out by considering all these wells separately in the base model and their effects on average reservoir pressure, production rate, and cumulative production have been identified. This study is concluded by a recovery factor comparison chart which analyses these strategies and a best selection is made. This study will serve as a prototype to select best and feasible development technology in various basins having tight gas formation.

Keywords: Tight gas, Development Strategies, Production Optimization

1. INTRODUCTION:

A reservoir is termed as tight if it has low matrix permeability about 0.1 md or less and a matrix porosity of about 10 percent. A tight gas reservoir contains gas in its small pores. They have low productivity as compared to conventional reservoirs. According to Tight Gas Policy-2011, Pakistan, it is defined as a reservoir with natural gas that has an effective permeability of less than 1.0 md (clause-

5). From a study conducted, the proven tight gas reserves in various basins and horizons of Pakistan comes under the range of 24 - 40 TCF. Sui Upper Limestone, Pirkoh Limestone, Habib Rahi Limestone, Sembar Sands & Siltstones and Lower Goru Tight Sands are important candidates of TGR in Pakistan.

There have been a lot of technologies introduced to enhance the productivity of Tight Gas Reservoirs. The economic development of Tight Gas Reservoirs requires proper designing and handling of both the reservoir and the wellbore.

2. MODEL DESCRIPTION:

The unconventional tight reservoir in this study has an average permeability of around 0.00363 md with 6% of porosity. The kv/kh ratio is assumed to be 0.1. The reservoir has no natural fractures, therefore, a single porosity simulation model is used in this study to quantify the flow the behavior in the small pores of tight sand. For base case, a vertical well is installed with the simulated reservoir (Fig. 1). The well is perforated in 2nd layer of simulated reservoir.

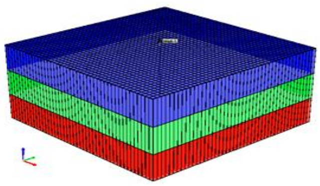

Figure 1: Simulation model with vertical well (Base Case)

3. DEVELOPMENT OF TIGHT GAS RESERVOIR:

Tight gas reservoir can be developed by four possible ways. The strategies include vertical well, vertical well with fracture, horizontal well, and multistage fractured horizontal well.

3.1. Vertical Well:

Since tight gas reservoir has low permeability, therefore, vertical well will not provide required production rate and it would not be economically justifiable for production. From Figure 2, it is evident that well is producing at a very low production rate which is not technically feasible for the company. The recovery factor is also very low as shown in Figure 3.

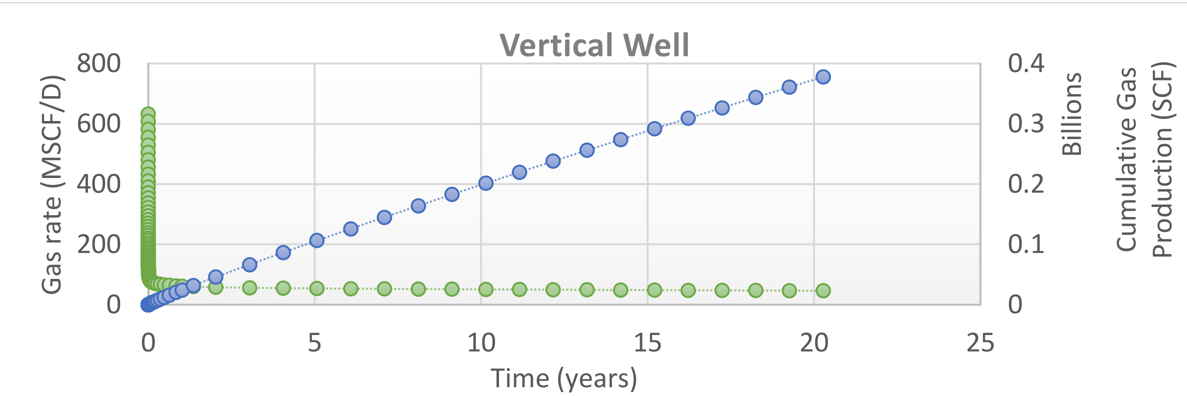

Figure 2: Production response of Vertical Well

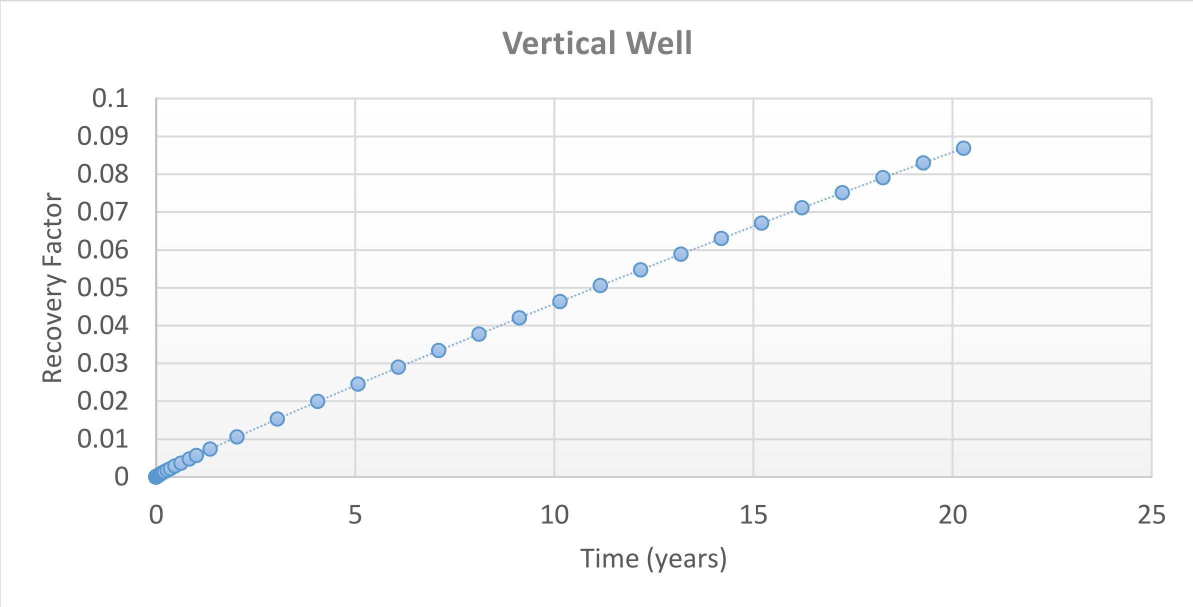

Figure 3: Recovery Factor of vertical well

Furthur, the pressure depletion is also low which results in less production of gas as shown in Fig. 4.

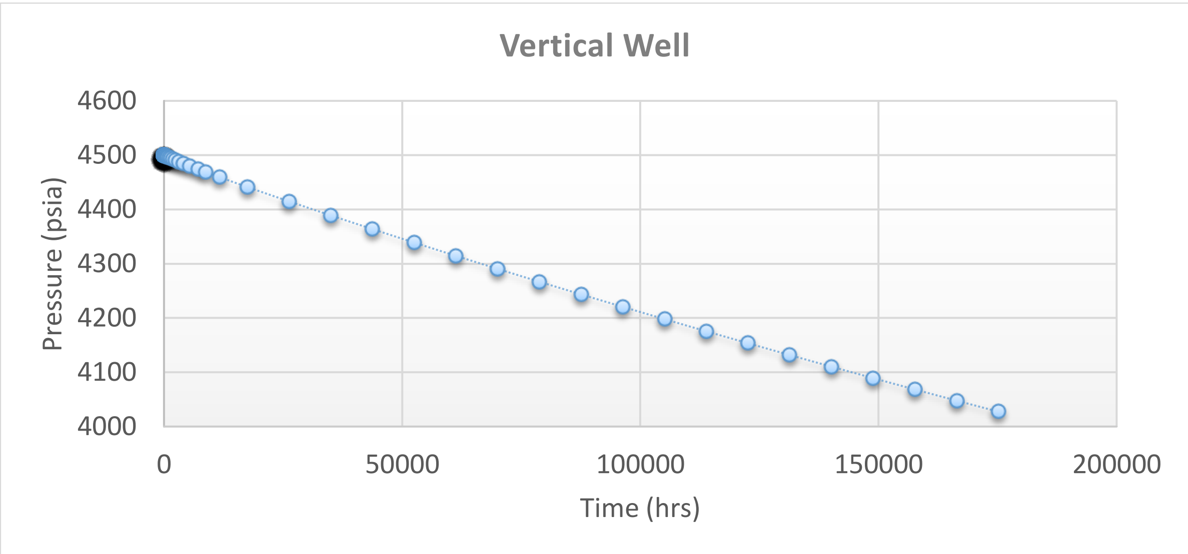

Figure 4: Pressure response up to 20 years

3.2. Vertical Well with Fracture:

The next strategy is to create a fracture perpendicular to vertical well. This would allow gas to flow more easily from reservoir to well as compared to vertical well. This will result in increased production (Fig. 5). Fracture half-length highly affect the production in this strategy. The fracture half-length, in this case, is 300 ft. The fracture is developed by introducing transmissibility multipliers and local grid refinement. This increased production results in increased recovery factor of gas as shown in Figure 6. Also, the pressure depletion is more than simple vertical well which causes more production as compared to vertical well. This depletion is shown in Figure 7.

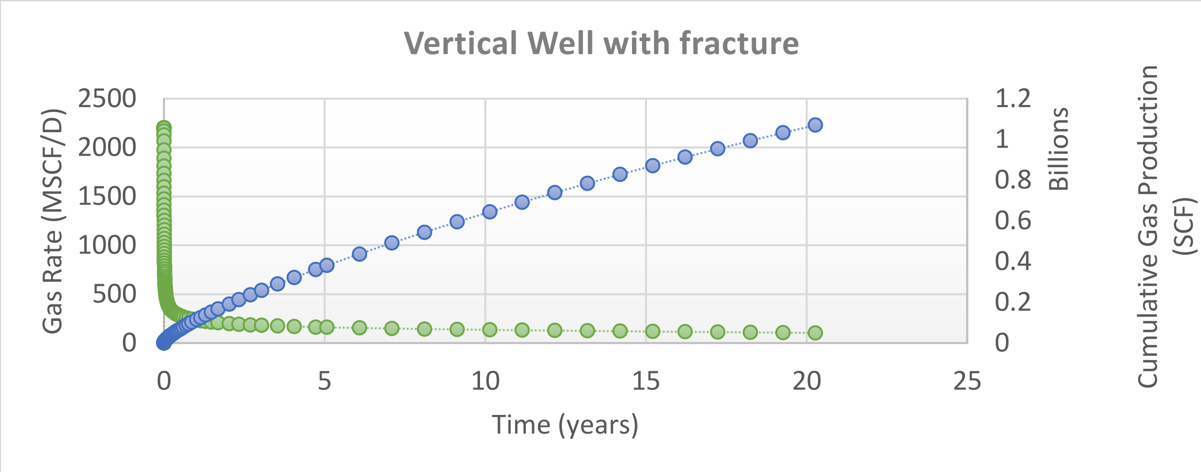

Figure 5: Production profile of Vertical Well with fracture upto 20 years.

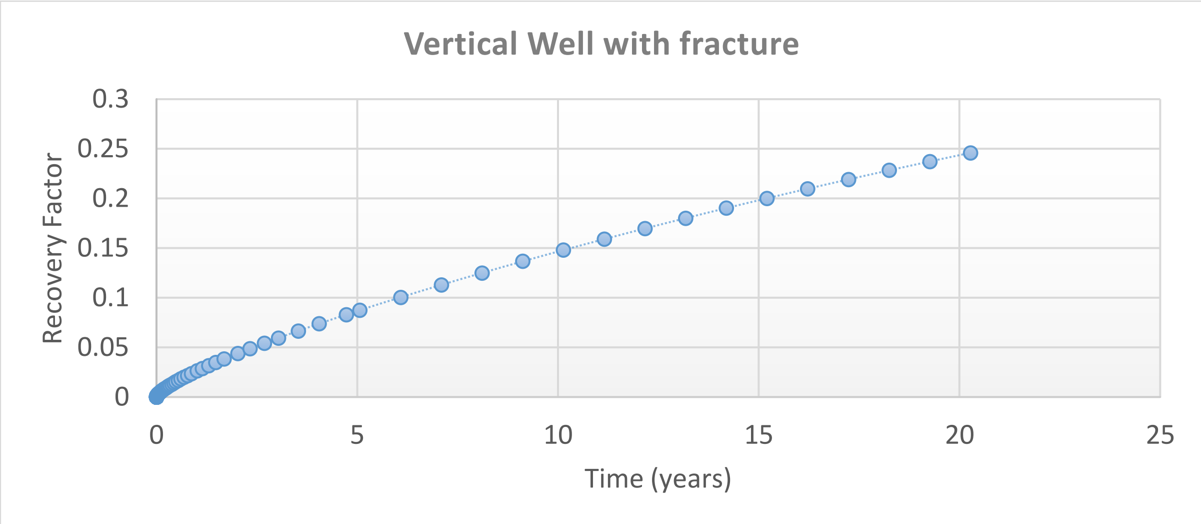

Figure 6: Recovery Factor of vertical well with fracture up to 20 years

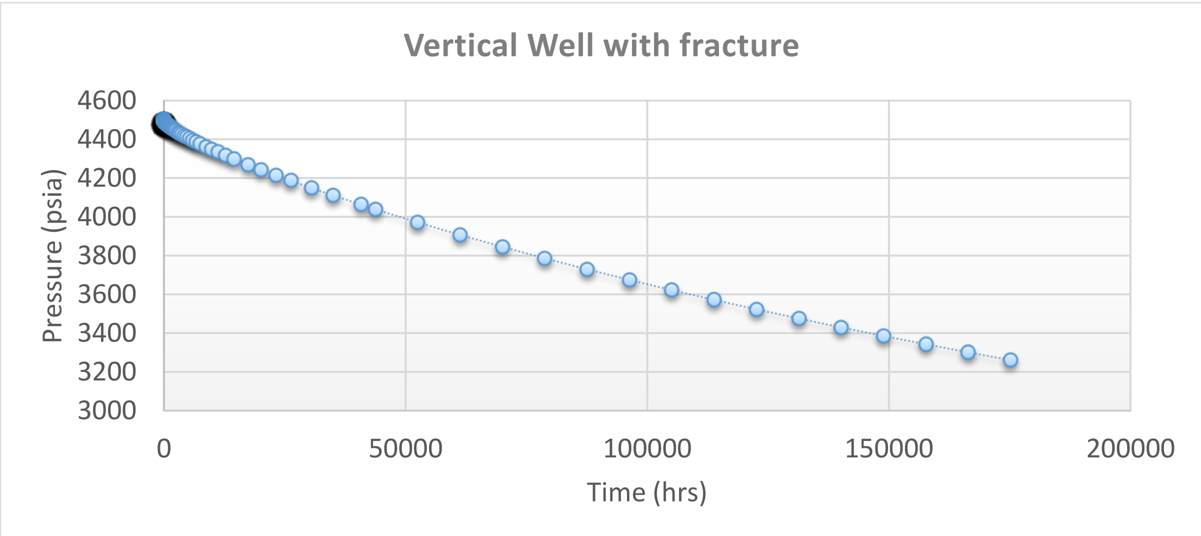

Figure 7: Pressure response up to 20 years (Vertical well with fracture)

3.3. Horizontal Well:

The horizontal well is drilled at an angle of 90^0 from the vertical well. It provides more exposure to reservoir area than the above techniques and hence greater production as evident from Figure 8 and Figure 9. Also, the pressure depletion is more than vertical and vertically fractured well (Figure 10).

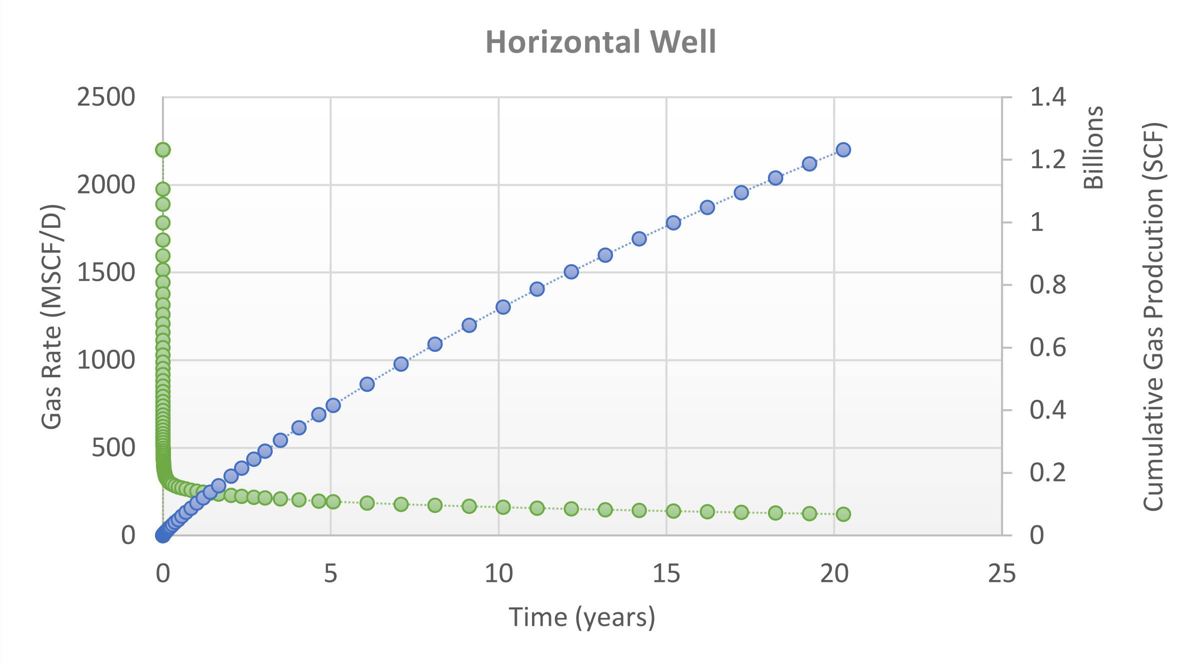

Figure 8: Production profile of 20 years of production (horizontal well)

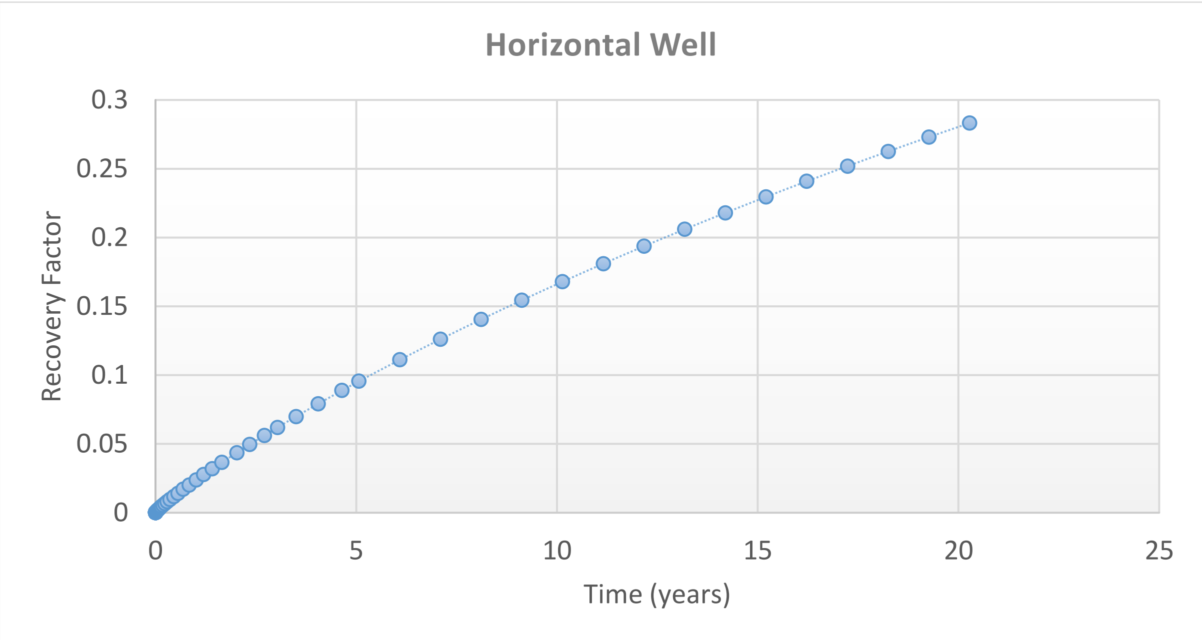

Figure 9: Recovery Factor of horizontal well up to 20 years

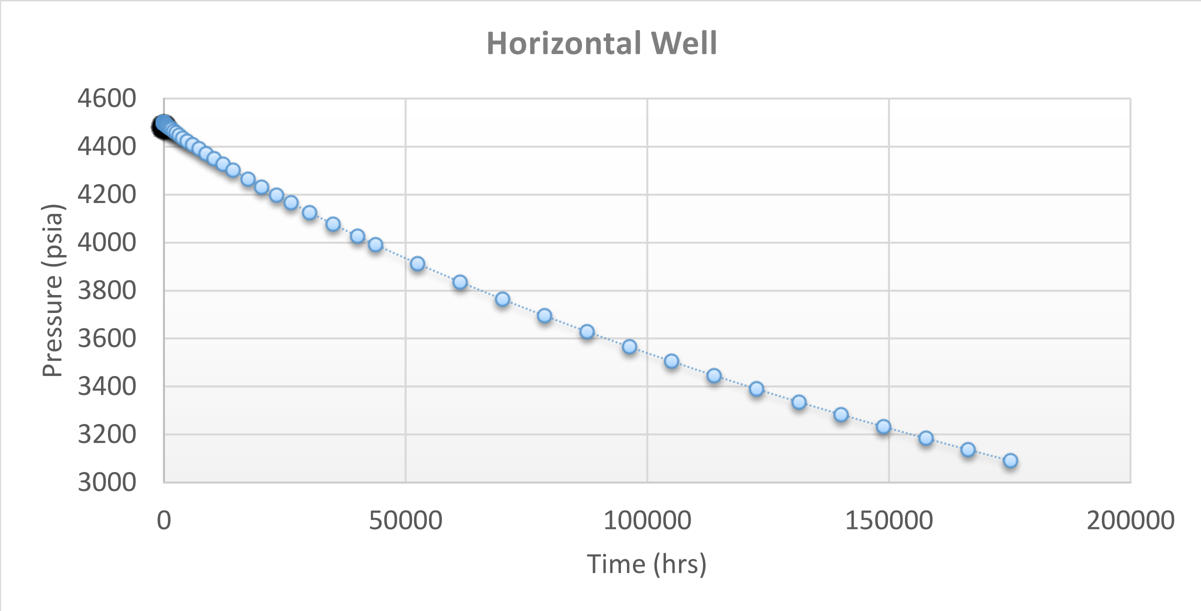

Figure 10: Pressure response up to 20 years (Horizontal Well)

3.4. Multi-stage hydraulically fractured Horizontal Well

In this strategy, horizontal well is drilled and fractures are created over the entire horizontal well. This simulated case consists of 1000 ft of horizontal well length with around 10 hydraulic fractures. This strategy not only have greater contact area with reservoir but also higher stimulated reservoir volume (SRV) because of fractures. This results in higher pressure depletion (Fig. 11), more gas production (Fig. 12) and higher gas recovery factors (Fig. 13).

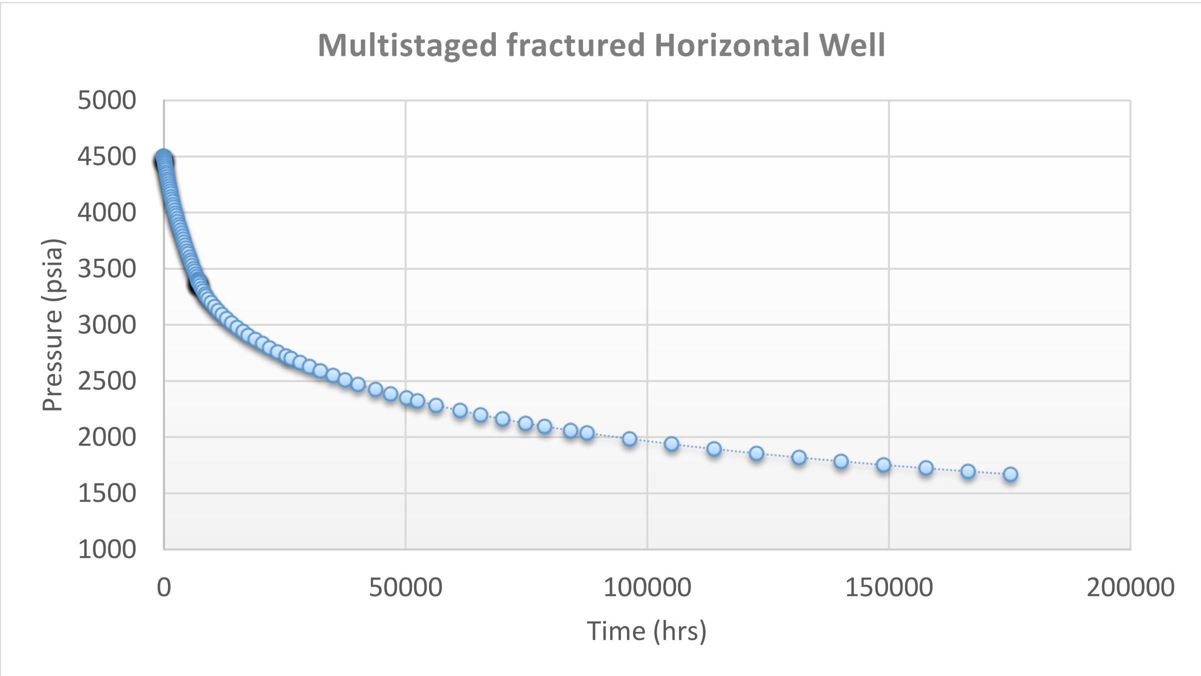

Figure 11: Pressure response up to 20 years (multi-stage hydraulically fractured horizontal well)

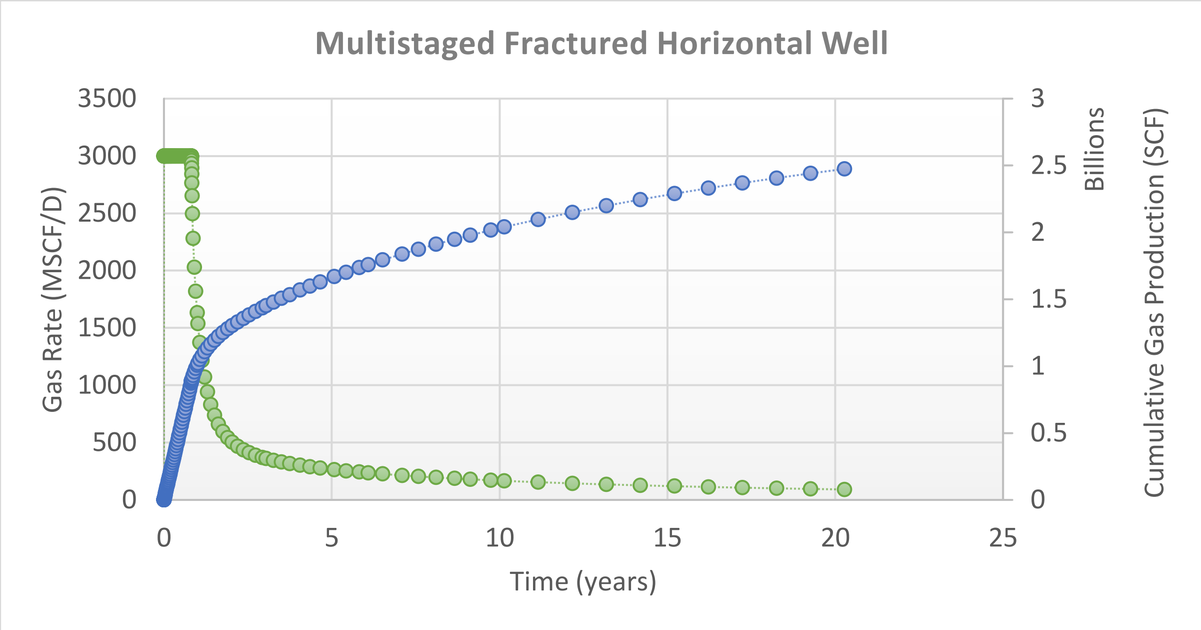

Figure 12: Production profile of 20 years of production (Multistaged hydraulically fractured horizontal well)

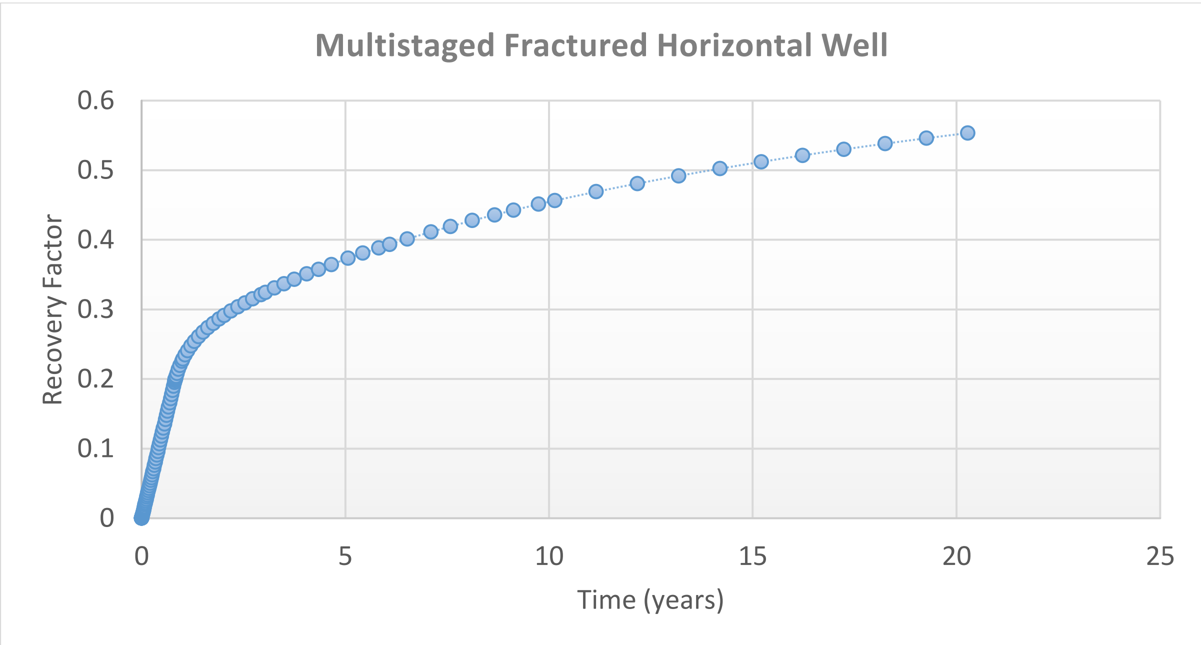

Figure 13: Recovery Factor of multistaged hydraulically fractured horizontal well up to 20 years

4. RESULTS AND DISCUSSION:

After analyzing Figure no: 2, 5, 8 and 12, it has been found that multistage hydraulically fractured horizontal well provides greater production rate and cumulative production as compared to other technologies. The production rate observed during 20 years of production of reservoir from multistage hydraulically fractured horizontal well is way much higher than other technologies. Also, the

cumulative production from such strategy is about 2.47 BSCF which is 6.67 times higher than reservoir base case. Figure 14 and figure 15 shows the comparison of production rates and gas cumulative production respectively of all the above four types of wells.

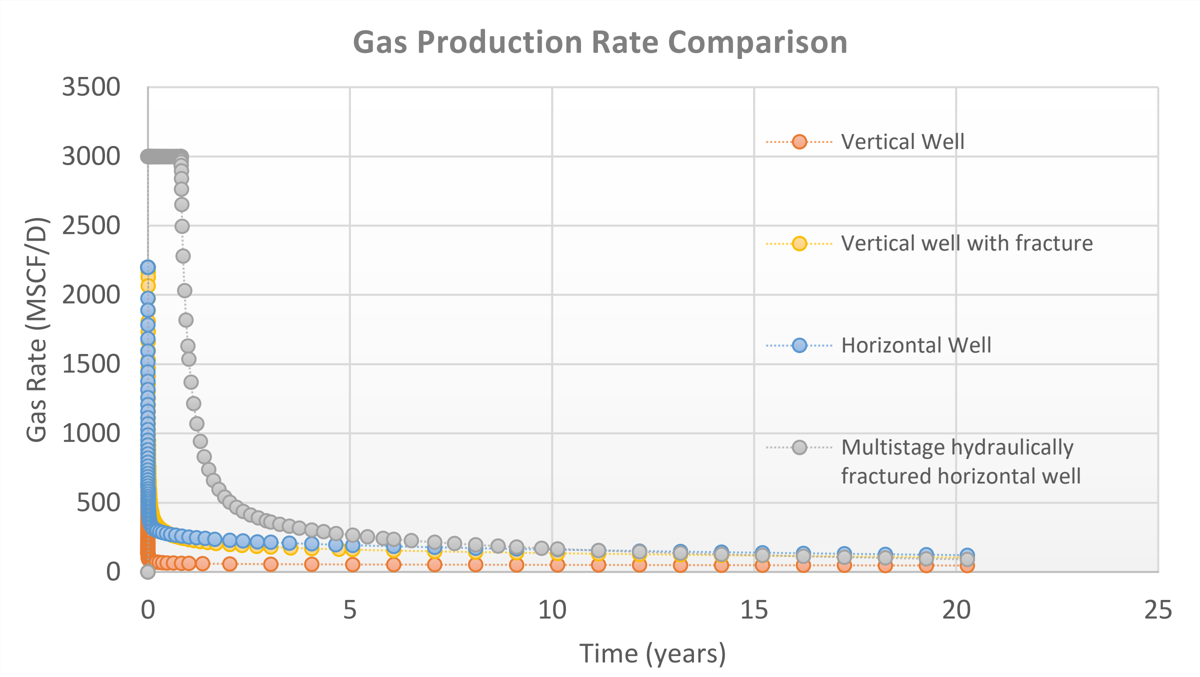

Figure 14: Production rate comparison up to 20 years of production.

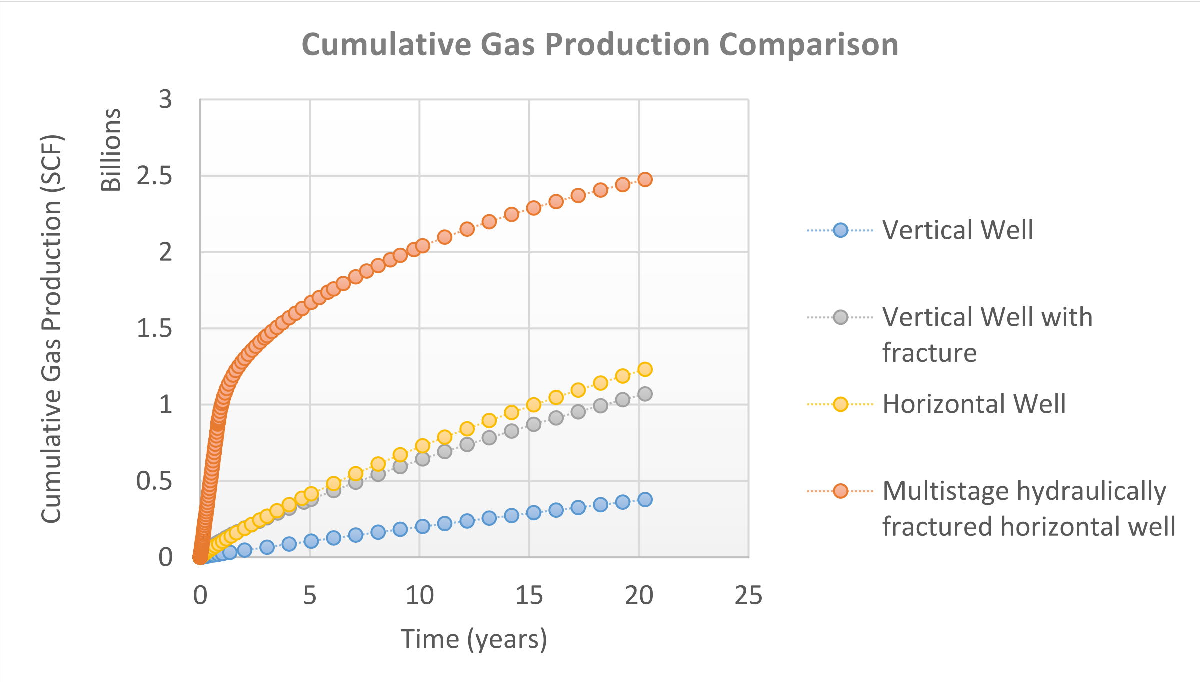

Figure 15: Gas Cumulative Production comparison up to 20 years of production.

It has been also found through the analysis of simulated reservoir that Gas Recovery Factor of multistage hydraulically fractured horizontal well is 55.34% while horizontal well, vertical well with fracture and vertical well has Recovery Factor of 28.32%, 24.59% and 8.6% resp. as shown in Figure 16. Hence, technically multistage hydraulically fractured horizontal well is the best candidate for tight gas reservoir. But, economic constraints must also be taken into consideration while selecting such wells. These percentages may vary depending upon the characteristics of reservoir.

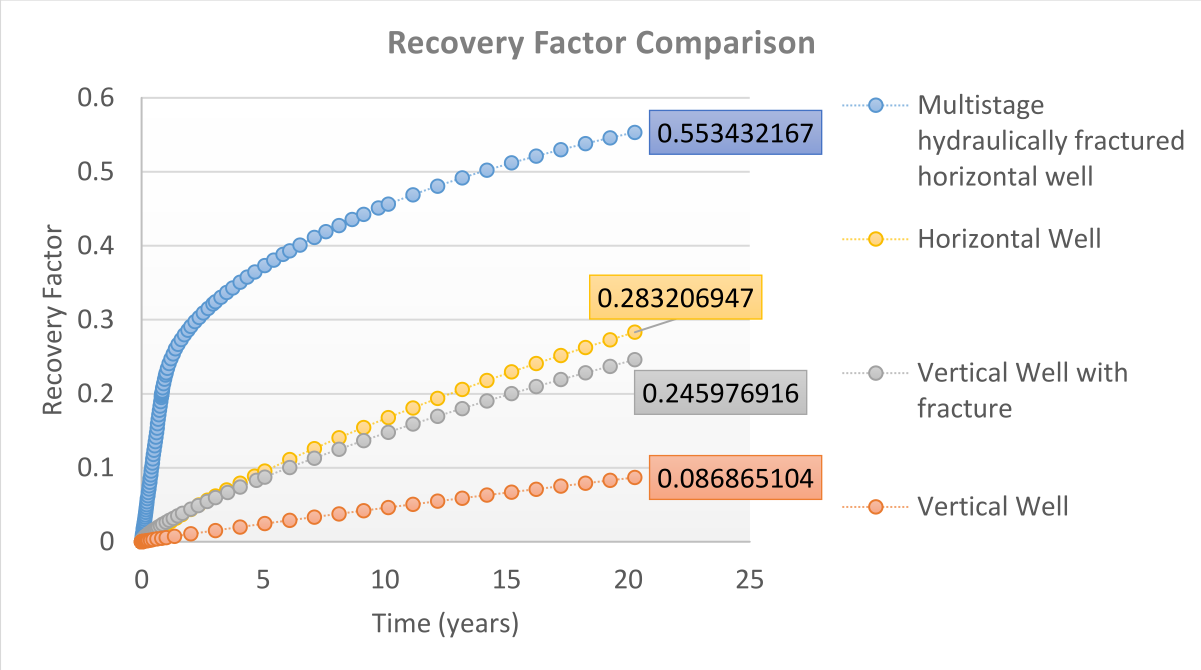

Figure 16: Gas Recovery Factor Plot

5. CONCLUSION

It is a known fact that large amount of hydrocarbons trapped in unconventional tight resources. However, their development is highly dependent on advanced production enhancement techniques and economics. This work focuses on the production obtained by different development strategies in a tight gas reservoir. It has been found in this study that higher production rates, cumulative production, and recovery rates can be observed with multi-staged hydraulically fractured horizontal well technically. Still, while selecting any well economic constraints must also be determined.

6. ACKNOWLEDGEMENT

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